Application of Prompt Gamma Activation Analysis (PGAA) to Oceanic Floor Geothermal Vent-Produced Sulfides*

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Prompt Gamma Activation Analysis (PGAA) is a nondestructive radioanalytical method capable of rapid, in situ, simultaneous, multi-element analysis involving the entire periodic table from hydrogen to uranium. Gamma rays produced instantaneously following neutron capture on a sample provide a unique energy and intensity signature for nearly every element. The gamma-ray spectra can span the range of 10 MeV and are often complex, but recent advances with Compton-suppressed Ge detectors and guided neutron beams have made PGAA more quantitative than in the past. A new PGAA gamma-ray library has been developed at Budapest that greatly improves the precision of the technique.

The measurements discussed here were performed at the 10 MW Budapest Research Reactor, Hungary. A beam of low-energy neutrons is transported 35 m from the reactor core by a slightly curved neutron guide made of glass coated with a nickel reflector. At the target the thermal-equivalent flux of the beam is $\sim 2.5 \times 10^{6}$ $cm^{-2}s^{-1}$. The beam is collimated to an area 2×2 cm and samples were placed in FEP Teflon bags. The detector system consists of a high-purity Ge detector surrounded by a BGO scintillator to reject Compton scattered photons. The detector system is shielded against neutron- and gamma-radiation background. A baseline suppression of ~6 was achieved at 1332 keV.

Spectra were collected in a 16,000 channel Canberra S100 MCA. Energy and efficiency calibrations were performed with well-known gamma rays from radioactive sources and (n,γ) reactions. The spectra were evaluated with *Hypermet PC* a complex γ-spectrum evaluation program developed at Budapest.

About twenty years ago the research submersible Alvin gathered samples from deep-sea hydrothermal vents on the Juan de Fuca Ridge off the Northwest US coast. Samples from these vents were analyzed using the PGAA technique. Examples of the results obtained for the analysis of two very different samples is shown in figure 1. Here the elemental concentrations are shown where the oxygen content, which is difficult to detect quantitatively, was calculated from the expected oxidation states. The first sample shows large amounts of SiO_2 while the second sample has significant quantities of CuS and very little silicon. Note the special sensitivity of PGAA to hydrogen, boron, and rare earth isotopes.

Footnotes and References

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ALU-1461-2R Sample

Z	El	c% el/ox	*unc%*
1	H	0.027	*4.39*
5	B	7E-04	*1.25*
11	Na	1.963	*2.7*
12	Mg	3.627	*5.31*
13	Al	7.059	*1.71*
14	Si	22.34	*1.45*
15	P	1.623	*14.6*
16	S	0.159	*6.21*
17	Cl	0.019	*2.85*
19	K	0.162	*5.56*
20	Ca	7.245	*1.86*
21	Sc	0.006	*8.45*
22	Ti	1.06	*0.98*
23	V	0.046	*5.43*
25	Mn	0.161	*2.35*
26	Fe	9.374	*0.93*
27	Co	0.006	*16.1*
48	Cd	2E-04	*13.1*
62	Sm	3E-04	*2.17*
64	Gd	6E-04	*1.77*
66	Dy	0.001	*12.9*

ALVIN 917-R4 Sample

Z	El	c% el/ox	*unc%*
1	H	0.36817	*1.14*
5	B	0.0022	*0.96*
11	Na	0.14038	*10.4*
12	Mg	1.83594	*10.1*
14	Si	0.55198	*9.66*
16	S	19.9647	*1.09*
17	Cl	0.19387	*0.9*
19	K	0.26935	*21.5*
20	Ca	11.3361	*1.66*
26	Fe	9.28137	*1.15*
28	Ni	1.16792	*2.28*
27	Co	0.00657	*17*
29	Cu	7.66534	*0.88*
30	Zn	1.36164	*3.97*
48	Cd	0.00352	*1.45*
62	Sm	0.00033	*10.2*
64	Gd	5E-05	*12.7*

Figure 1. Analysis of two samples from hydrothermal vents on the Jaun de Fuca Ridge.